

This brief is intended for Control Engineers and Technicians who are installing, programming and maintaining a MediaPro Control System that communicates on an Ethernet network. It is assumed that you have some understanding of MediaPro 4000 Systems, Show Control, Ethernet IP Networking and Windows PCs.

1) What hardware is needed to connect devices together on EtherNet?

1.a) At a minimum a Cat 5 CROSSOVER cable that can be connected directly between a PC and a ICM. (or between 2 PCs, or between any other typical Host devices).

1.b) Only slightly more involved, using a STRAIGHT Cat 5 cable between the ICM(s) and a Hub/Switch and another STRAIGHT Cat 5 cable between the PC and a Hub/Switch.

2) Network Cabling; What's in a cable, aren't they all the same?

Several companies have demonstrated 10BaseT, 100BaseTX and even 1000BaseTX (for a few feet) over **barbed wire** {uninsulated, unshielded, not paired} to attract attention (Anixter, Broadcom, Cisco, Interop Labs and others {If you are successful in actually implementing a reasonable sized LAN on barbed wire let us know!})

2.A) **Cable Standards and Specifications** {and proposed standards} (ANSI, Bellcore, CENELEC, EIA, IBM, IEC, IEEE, ISO, ITU, NEMA, TIA, UL) sure plenty exist; they overlap and vary in tolerances and parameters. For example, "EIA/TIA Cat 5" is not concerned with far end crosstalk, return loss or power sum.

There is no easy way to distinguish one Category/Class/Level/Type from another and cable construction and electrical performance vary widely among manufacturers. (Tolerances of Attenuation, Balance, Bandwidth, Capacitance, Delay Skew, Electromagnetic Compatibility, Far End CrossTalk, Impedance, Longitudinal Conversion Loss, Near End CrossTalk, Power Sum, Propagation Delay, Resistance, Return Loss, Wire Gauge, Solid/Stranded.)

2.A.1) **Categories** (ANSI, CENELEC, EIA, IEC, ISO, ITU, NEMA, TIA, UL), **Levels** (Anixter, NEMA, UL),

2.A.2) **Classes** (CENELEC, IEC, ISO, TIA) and **Types** (IBM, UL):

There are plenty of flavors, each with slightly different characteristics.

Obsolete: Up to 4 MHz: Cat 2; Up to 16 MHz: Type 1 9 (only 2 pairs); Up to 20 MHz: Cat 4 (**10BaseT**, 100BaseT2, 100BaseT4, 100BaseVG); Up to 100/300 MHz: Type 1A, 2A, 6A, 9A (only 2 pairs)

Up to 16 MHz: Cat 3, Class C (**10BaseT**, 100BaseT2, 100BaseT4, 100BaseVG)

Up to 100 MHz: **Cat 5**, Cat 5+, Cat 5e, Cat 5E, Class D (**10BaseT**, 100BaseT2, 100BaseT4, 100BaseVG, **100BaseTX**, *)

Up to 250 MHz: Cat 6, Class E, ALC 6, XP 6 (**100BaseTX**, 1000BaseT{125Mhz}, ATM{155MHz})

Proposed: Up to 350 MHz: Cat 7, ALC 7, XP 7 (1000BaseT{125Mhz}, ATM{155MHz}); Up to 600 MHz: Cat 7, Class F

* You might get away with 1000BaseT or ATM on Cat 5e/E depending on the manufacturer's tolerances.

2.A.3) To **Shield or Not** to shield:

Unshielded Twisted Pair Cable (**UTP**), {most common} has four twisted pairs {typically 100 Ohm +/- 15% impedance}.

Screened Twisted Pair (**ScTP**) also called (**STP**), has a single braided screen over all four pairs {typically 100 Ohm +/- 15% impedance}.

Foil Twisted Pair (**FTP**) also called (**STP**), has a single foil wrap over all four pairs {typically 100 Ohm impedance}.

Fully Shielded Twisted Pair (**SSTP**) also called (**STP**), each pair shielded and shield over all 4 pairs {typically 100 +/- 15% Ohms}.

Obsolete: ~~IBM STP Cable (**STP-A**), each pair foil shielded and braid over both (2) pairs; also called (**STP**) (typically 150 Ohms).~~

2.A.3.a) Shielded cable only blocks interference as long as the entire cable (end-to-end) is properly shielded and grounded.

If the cabling is going in conduit or a metallic cable tray, the conduit or tray needs to be earth grounded and bonded together electrically so the entire run has continuity. Do not connect the shield of the cable to the conduit, the shield should be able to be terminated or open (through a easy to install/remove jumper) at either/both ends through a [MOV/ZNR (-200-500v) in parallel with a 1MegOhm resistor (~1/4-1w) in parallel with a ~0.047 uf (0.01 - 0.1 uf) Capacitor (~200-500v)] to ground.

Keep the cable away from EMI noise sources, if you need to install the cable **in metallic conduit then use only STP cable**.

The electrical performance of unshielded cable, installed in a metallic conduit, may be adversely affected.

2.A.4) Don't forget about other installation concerns

Cables with non-toxic/low flammability jackets (in ducts, plenums, environmental air spaces).

Cable jackets for outdoor environments (moisture may erode the jackets of indoor PVC/Plenum in conduits).

Cable separation distance from other conductors (Insulation Voltage and EMI)

EIA/TIA 569, NFPA 70, NEC 800 and local building codes have more information.

3) Ethernet Connectors and Pinouts:

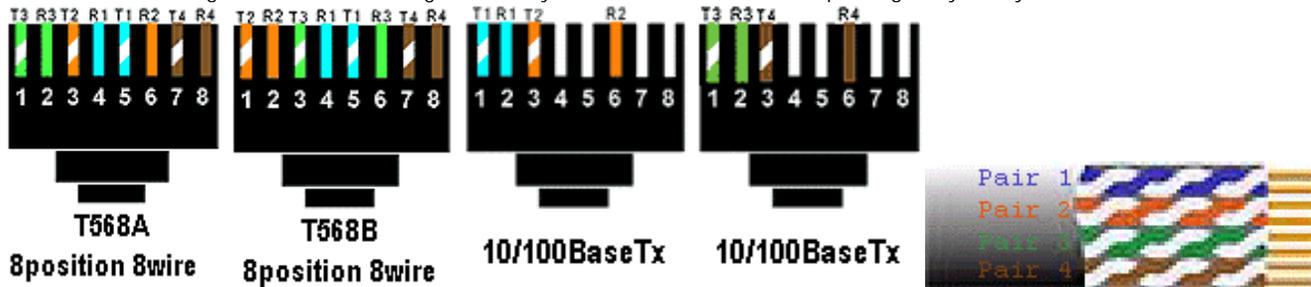
3.A) IP67 Connectors for Industrial environments are available (sealed against dust and liquid immersion):



- 3.A.1) IP67 RJ45 connectors and cables.
 - 3.A.1.a) RJ-Lnxx (Woodhead)
 - 3.A.1.b) VARIOSUB (Phoenix Contact)
- 3.A.2) RJ45 adapters to M12 IP67 connectors and cables.
 - 3.A.2.a) EtherMATE (Lumberg)
 - 3.A.2.b) eurofast (Turck/InterlinkBT)

3.B) A straight/normal connector cable end will look the same on both ends, a cross/flip cable will look like A on one end and B on the other end.

Viewed as looking into a Jack, or holding a cable in your hand with the connector pointing away from you and with the tab down.



There is probably every variation of color layout used somewhere.

What is important is that the pairs don't get split, the polarity is correct and that the wires land on the correct pins. (1+ and 2- is always a twisted pair. 3+ and 6- is always a twisted pair.)

3.B.1)

10BaseT/100BaseT STRAIGHT Cable Pinout				
2 pr Striped Color	4 pr Striped Color	One End	Signal	Other End
White/Blue	White/Orange	Pin 1	(TD+)	Pin 1
Blue	Orange	Pin 2	(TD-)	Pin 2
White/Orange	White/Green	Pin 3	(RD+)	Pin 3
	Blue	Pin 4	(Not used)	Pin 4
	White/Blue	Pin 5	(Not used)	Pin 5
Orange	Green	Pin 6	(RD-)	Pin 6
	White/Brown	Pin 7	(Not used)	Pin 7
	Brown	Pin 8	(Not used)	Pin 8

Straight/Normal cables connect a device to a hub/switch.
Straight cables also connect between a normal hub/switch port and a crossover/flipped hub/switch port.

3.B.2)

10BaseT/100BaseT CROSSOVER Cable Pinout				
2 pr Striped Color	4 pr Striped Color	One End	Signal	Other End
White/Blue	White/Orange	Pin 1	(TD+)	Pin 3
Blue	Orange	Pin 2	(TD-)	Pin 6
White/Orange	White/Green	Pin 3	(RD+)	Pin 1
	Blue	Pin 4	(Not used)	Pin 4
	White/Blue	Pin 5	(Not used)	Pin 5
Orange	Green	Pin 6	(RD-)	Pin 2
	White/Brown	Pin 7	(Not used)	Pin 7
	Brown	Pin 8	(Not used)	Pin 8
Crossover/Flip/X cables connect between two devices without using a hub/switch. Crossover cables also connect between two normal hub/switch ports.				

4) Extending and Interconnecting LANs

Can't the cable just be made longer?

4.A) Signal Loss (attenuation):

The 10/100BaseT (wire) max. unrepeatable cable segment length is **100 meters, (between NICs, Hubs, Bridges, Switches & Routers).**

The distance is based on signal loss in db (11.5db @ 10Mbps maximum loss source to destination)

{This means your mileage may vary, several manufactures advertise up to 150 meters and still comply with emission limits.}

4.B) Collision Domain :

10BaseT (wire) maximum network length of 500-2500 meters (across all segments between Bridge, Switch, Router).

100BaseTx (wire) maximum network length of 205 meters (across all segments between Bridge, Switch, Router).

100Base-Fx (multi-mode fiber), Half Duplex (HD) maximum length of 400 meters (across all segments between Bridge, Switch, Router).

100Base-Fx (multi-mode fiber), Full Duplex (FD) maximum length of 2000 meters (across all segments between Bridge, Switch, Router).

The distance is based on round-trip propagation delay (the time it takes for all devices in the collision domain to see another device's transmission before the device stops transmitting) {this includes propagation delay of the wire, hub latency, network interface cards, ...}.
{Once again this means your mileage may vary, feel free to calculate it per 802.3 but all you are likely gain is ~20 meters, signal loss may eliminate that too.}

4.B.1) 5-4-3 Rule (5 segments, 4 repeaters, 3 populated segments):

Between Bridges/Switches, there may be no more than five (5) repeated/hubed segments, nor more than four (4) repeaters/hubs between any two Ethernet devices; and of the five cable segments only three (3) may be populated.

4.B.2) What happens if the cable is longer than the "calculated/best common practice" segment length? There are more collisions caused by the devices at the far ends, resulting in less determinism (MAC jam, back off and retry timeout, jitter, latency)

4.C) Latency

Latency is a measurement of the delay between the sending of a packet at the source end & the reception of the packet at the destination end (this includes propagation delay of the wire {~5.48nsec/meter}, hub/switch/router latency, network interface cards, ...).

The closer a device is to zero latency, the better. The latency information provided below is based on equipment manufacturer's data sheets and third party benchmark results {Once again, your mileage may vary depending on the device's performance and traffic load}.

4.D) **Hub/Repeater** (OSI layer 1, Physical/Electrical/Optical, Mechanical) extends cable distance limits by connecting two segments of LAN cable & reshapes the signal (Like a Party line only one device can talk at a time, and everyone hears what anyone says) {Same collision domain}. {Don't forget the 5-4-3 rule}

4.D.1) Hubs/Repeaters typically have a latency in the range of ~460nsec-2.1usec.

Hubs/Repeaters square up, retimes and amplifies the signal; they do not inspect/evaluate the contents of the packet at any level.

4.E) **Switched Hub or Dual/Multi-Speed Hub** (OSI layer 1 Physical/Electrical and layer 2 DataLink/Ethernet Frame) Have a Bridge (2 port switch) between the 10Mbit and 100Mbit ports {Devices at the same speed are in the same collision domain, devices at different speeds are in separate collision domains}. {The 5-4-3 rule still applies unless connections between switched hubs are at a different speed than the host devices connected to the hubs.}

4.F) **Switch/Bridge** (OSI layer 2, DataLink/Ethernet Frame) isolates traffic between networks by filtering MAC addresses (low-level Ethernet hardware addresses) {separate collision domains}.

4.F.1) Cut-through switches typically have a latency in the range of ~2.2usec-35usec.

Cut-through switching sends the frame (packet) to the MAC destination as soon as the first 14 bytes of the frame are read. The delay is minimal and the packets reach their destination in the shortest possible time.

The frames are sent through the switch as a continuous flow of data, the transmit and receive rates are always the same. Because of this, cut-through switching cannot pass frames to higher speed networks, for example, to forward packets from a 10Mbps to a 100Mbps Ethernet network.

Since the switch has forwarded most of the frame when the CRC is read, the switch cannot discard frames with CRC errors. However, the CRC check is still made and, if errors are found, an error count is updated.

Cut-through switching is recommended for networks intended to provide one switch port per user, or for lightly loaded networks. It is essential for multimedia applications and ideal for workgroup environments where minimum delays are required.

4.F.2) Fragment-free switches typically have a latency in the range of ~6.4usec-115usec.

Fragment-free switching checks that there are no collisions within the first 64 bytes of the frame (packet) the minimum valid message size required by the IEEE 802.3 specification. This guarantees that message fragments less than 64 bytes (runts) are not forwarded to other network segments. Runts are typically the result of collision fragments.

Fragment-free switching offers a compromise between cut-through (which offers the fastest possible forwarding at the expense of error checking) and store-and-forward (which offers maximum error checking at the expense of forwarding speed), to provide sufficient error checking to eliminate the most common errors.

The frames are sent through the switch as a continuous flow of data, the transmit and receive rates are always the same. Because of this, fragment-free switching cannot pass frames to higher speed networks, for example, to forward frames from a 10Mbps to a 100Mbps Ethernet network. Therefore, if you opt for fragment-free switching, you cannot make direct connections to higher speed networks from that port.

4.F.3) Store-and-forward switches typically have a latency in the range of ~7.2usec-1.5msec.

Store-and-forward switching temporarily stores a frame (packet) and checks it against the CRC field. If the frame is error free, it is forwarded; otherwise, it is discarded. Store-and-forward switching is therefore the best forwarding mode to prevent errors being forwarded throughout the network. The buffering used by store-and-forward also allows the switch to dispatch frames at a different rate than it receives them for example, to forward frames from a 10Mbps network to higher speed networks such as a 100Mbps Ethernet.

4.G) **Router** (OSI layer 3, Network/SubNet/IP Packet) connects two or more networks of the same type, and selectively directs and filters packets pertaining to the protocol used on the wire (A TCP/IP router directs and filters IP addresses) {separate collisions domains and subnets}.

4.G.1) Routers/Layer 3 Switches typically have a latency in the range of 153usec-3msec)

Routers temporarily store a packet and check it against the IP header fields. If the packet is error free, the parameters are valid {Type of Service (TOS), Control Flags, Time to Live (TTL) and Options} and the destination IP address is in its route table, it is forwarded, otherwise, it is discarded and potentially an Internet Control Message Protocol (ICMP) {error} message is sent back to the source IP address.

4.H) **Gateway/Routers** process packets at higher levels (OSI layer 4-7, UDP/TCP/FTP/HTTP) for Security (Firewall), Network Address Translation (NAT), Port Address Translation (PAT), Proxy, Content Control Policy, Virtual Private Network (VPN), Quality of Service (QOS), Traffic Prioritization, Bandwidth Limiting, Load Balancing, Cache.

4.H.1) Gateway/Routers typically have a latency of a Layer 3 Router +?)

Gateways temporarily store packets and depending on the rules setup in the gateway, the packet may be delayed, forwarded, redirected, modified or discarded. The latency can be hard to determine, because of the priority and limits based on the payload of the packet (Layer 3 {IP, ARP, ICMP}, Layer 4 {UDP, TCP}, Layer 5/6 {NetBIOS, DNS, HTTP, FTP, SSL}, even Layer 7 {URL, HTML, content filtering [PICS, RSACI, ICRA, ESRBI], application specific data}) may have an effect how a packet is handled.

4.H.7) Wide Area Network (**WAN**)/Internet Access Devices (**IAD**) devices (Analog Modem, DSL, T1, Cable Modem) typically have a latency in the range of 20msec to 200msec (the latency of a Layer 3 Router +?).

5) **Reliability and Determinism** of the network:

5.A) Keep control networks isolated/separate from other networks, especially office networks (Many Ethernet devices will babble constantly on the Ethernet).Example: PCs and Printers running NetBEUI, or NetBIOS over TCP/IP or IPX will babble constantly to identify themselves (Which speeds up locating devices in the Windows Network Browser).

5.B) MediaPro 4000 Systems use Master/Slave protocols that provide real time deterministic communication between the ICMs.

5.C) Full Duplex Switches allow communications to travel in both directions between Ethernet devices simultaneously (virtually eliminating collisions).

5.D) Redundant "failover" paths can be cabled between switches, duplicate paths are disabled and are re-enabled when an active link fails.

5.D.1) Spanning Tree protocol is available in many Ethernet switches and allows the connection of Ethernet switches into tree and ring structures.

5.D.2) Proprietary protocol, Doubled/parallel paths redundancy and Ring path redundancy structures are available in some switches.

5.E) Industrial Ethernet switches are available with enclosures for Industrial environments, Din Rail Mounting and 24vdc supplies.

For more information, see the following references:

<http://anitech-systems.com/> Anitech System's Web Site
<http://anitech-systems.com/MP4000/manual/> Manuals
<http://anitech-systems.com/MP4000/manual/briefs/> Briefs

http://www.3com.com/other/pdfs/infra/corpinfo/en_US/501302.pdf Understanding IP Addressing: Everything you ever wanted to know

<http://anixter.com/>, <http://anixter.com/techlib/>, Many documents relative to Ethernet cables, by Anixter

Surviving the Manufacturing and Industrial Environment, by Anixter, Cisco and Rockwell/Allen-Bradley
http://www.ciscoworldmagazine.com/webpapers/2001/06_rockwell.shtml, <http://www.ab.com/networks/enetpaper.html>

http://www.rjlnxx.com/ENET_on_the_factory_floor.pdf, Industrial Ethernet Connectivity, by RJ-Lnxx

Connectivity: The Last Frontier, Best Industrial Installation Practices, by Industrial Ethernet Book, RJ-Lnxx and Woodhead Industries
<http://ethernet.industrial-networking.com/articles/i06connectivity.asp>

<http://ieee.org/>, <http://standards.ieee.org/reading/ieee/std/lanman/>
Carrier sense multiple access with collision detection (**CSMA/CD**) access method and physical layer specifications
<http://standards.ieee.org/reading/ieee/std/lanman/802.3-2000.pdf>

<http://www.iana.org/>, <http://www.iana.org/assignments/ipv4-address-space> Internet Protocol (IPv4) **Public/Global Address Space**

<http://www.ietf.org/>, Automatic Private IP Addressing (**APIPA**) [169.254.x.x]
<http://search.ietf.org/internet-drafts/draft-ietf-zeroconf-ipv4-linklocal-04.txt>

<http://www.rfc-editor.org/>, The RFC Editor is the publisher of the RFCs and is responsible for the final editorial review of the documents.
The Requests for Comments (**RFCs**) form a series of notes that discuss many aspects of computer communication.

<http://www.rfc-editor.org/rfc/bcp/bcp5.txt> <http://www.rfc-editor.org/rfc/rfc1918.txt> Address Allocation for **Private Internets**

<http://www.rfc-editor.org/rfc/rfc950.txt> Internet Standard **SubNetting** Procedure

<http://www.rfc-editor.org/rfc/rfc1519.txt> Classless Inter-Domain Routing (**CIDR**)

<http://www.rfc-editor.org/rfc/std/std3.txt> Communication, Application and Support Requirements for **Internet Hosts**

<http://www.rfc-editor.org/rfc/std/std6.txt> User Datagram Protocol (**UDP**)

<http://www.rfc-editor.org/rfc/std/std5.txt> Internet Protocol (**IP**)

<http://www.rfc-editor.org/rfc/std/std37.txt> <http://www.rfc-editor.org/rfc/std/std38.txt> **ARP**: Convert IP Addresses to Ethernet MAC Address

<http://www.rfc-editor.org/rfc/std/std2.txt> <http://www.rfc-editor.org/rfc/rfc1700.txt> **Assigned Numbers**: Addresses, Ports, Protocols

<http://www.rfc-editor.org/rfc/std/std1.txt> Internet Official Protocol Standards

[ISBN 3-540-96651-X](#) **Introduction to TCP/IP** by John Davidson

[ISBN 1-565-92660-9](#) **Ethernet the Definitive Guide** Designing and Managing Local Area Networks by Charles E. Spurgeon

[ISBN 0-471-12706-X](#) **Ethernet Networks** Design, Implementation, Operation, Management 2nd ed. by Gilbert Held

[ISBN 0-201-63495-3](#) **TCP/IP Illustrated TCP for Transactions** Vol. 3 by W. Richard Stevens

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[ISBN 0-131-62959-X](#) **Computer Networks** 2nd ed. by Andrew S. Tanenbaum

[ISBN 0-070-46320-4](#) **Ethernet Management** Guide – Keeping the Link by Martin Nemzow,

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